CHAPTER 13

TEST EQUIPMENT

13-1. Equipment maintenance.

Accurate and appropriate test equipment is critical to the maintenance of electrical equipment. Listed in table 13-1 are some of the tools and equipment that each military facility electrical shop should possess. A brief description of the equipment application is also given. To perform specialized testing, such as infrared or insulation resistance testing, special equipment may be rented, or purchased depending upon projected future use. This testing may be performed by experienced military facilities personnel, or it may be contracted to an electrical testing shop. In the sections that follow three of the more common and versatile test equipment available are described: the volt-ohm-miniammeter, the clamp-on volt-ammeter, and the megohmmeter. As in the use of all test equipment, these devices should be used in strict compliance with the manufacturer's instructions and recommendations. Failure to do so may result in injury to personnel making the tests as well as produce meaningless data.

13-2. Volt-ohm-milliammeter (VOM).

This meter incorporates the functions of the voltmeter, ohmmeter and milliammeter into one instrument. A VOM can be used to measure AC or DC voltage, current and resistance, with several ranges for each function. There are also solid-state VOMS which perform the same functions. For precise operating procedures, the manufacturer's instructions must be referenced. A VOM which measures true RMS should be used.

a. Safety precautions. A VOM is usually designed to prevent accidental shock to the operator when properly used. However, careless use of the instrument can result in a serious or fatal accident. The VOM should only be used by personnel qualified to recognize shock hazards and trained in the safety precautions required to avoid possible injury. Safety precautions are as follows:

(1) Do not work alone when making measurements of circuits where a shock hazard can exist. Notify another person that you are, or intend to make such measurements.

(2) Locate all voltage sources and accessible paths prior to making measurement connections. Check that the equipment is properly grounded and the right rating and type of fuse(s) are installed. Set the instrument to the proper range before power is applied.

(3) Remember, voltages may appear unexpectedly in defective equipment. An open bleeder resistor may result in a capacitor retaining a dangerous charge. Turn off power and discharge all capacitors before connecting or disconnecting test leads to and from the circuit being measured.

(4) For your own safety, inspect the test leads for cracks, breaks or flaws in the insulation, prods and connectors before each use. If any defects exist, replace the test leads immediately.

(5) Do not make measurements in a circuit where corona is present. Corona can be identified by its sound, the odor of ozone or a pale-blue color emanation from sharp metal points in the circuit.

(6) Hands, shoes, floor and workbench must be dry. Avoid making measurements under humid, damp, or other environmental conditions that could affect the dielectric withstanding voltage of the test leads or instrument.

(7) For maximum safety, do not touch test leads or instrument while power is applied to the circuit being measured.

(8) Use extreme caution when making measurements in a radio frequency (RF) circuit where a dangerous combination of voltage could be present, such as in a modulated RF amplifier.

(9) Do not make measurements using test leads which differ from those originally furnished with the instrument.

(10) Do not come into contact with any object which could provide a current path to the common side of the circuit under test or power line ground. Always stand on a dry insulating surface capable of withstanding the voltage being measured, or that could be encountered.

(11) The range or function switch should only be changed when the power to the circuit under measurement is turned off. This will provide maximum safety to the user, eliminate arcing at the switch contacts and prolong the life of the meter.

b. Operation. Before making any measurements, the VOM pointer must be adjusted to zero. With the VOM in operating position, check that the pointer indicates zero at the left side of the scale when there is no input. If pointer is off zero, adjust the screw located in the case below center of the dial. Use a small screwdriver to turn the screw slowly clockwise or counterclockwise until the pointer is exactly over the zero mark at the left side of the scale. With the indicating pointer set on the zero mark, reverse the direction of rotation of the zero adjuster. Rotate

Table 13-1. Tools and equipment for effective electrical maintenance.

TOOLS OR EQUIPMENT	APPLICATION
1. Voltmeters, ohmmeters, clamp-on ammeters, wattmeters, clamp-on P.F. meters.	Measure circuit voltage, resistance, current and power. Useful for circuit tracing and troubleshooting.
2. Potential and current transformers, meter shunts.	Increase range of test instrument to permit reading of high-voltage and high-current circuits.
3. Tachometer	Checks rotating machinery speeds.
4. Recording meters, sequence event recorder.	Provide permanent record of voltage, current, power, temperature, etc. on charts for analytical study.
5. Insulation resistance tester, thermometer, psychrometer.	Test and monitor insulation resistance; use thermometer and psychrometer for temperature humidity correction.
6. Transistorized stethoscope.	Detect faulty rotating machinery bearings; leaky valves.
7. Air gap feeler gauges.	Check motor or generator air gap between rotor and stator.
8. Spring tension scale.	Checks brush pressure on D.C. motor commutators or on A.C. motor slip rings; test electrical contact pressure on relays, starters or contactors.
9. Magnifying glass, binoculars.	Use magnifying glass to examine brushes, commutators or small electrical contacts or parts; binoculars allow close inspection of remote parts.

Table 13-1. Tools and equipment for effective electrical maintenance--continued.

TOOLS OR EQUIPMENT	APPLICATION
10. Motor rotation tester.	Checks direction of motor rotation before connection.
11. Phase tester.	Checks phase rotation of a circuit.
12. Oscilloscope, vacuum-tube voltmeter, high impedance meters.	Used for electronic circuit testing.
13. Variable autotransformer.	Allows testing of circuits at reduced voltage.
14. Low-resistance tester.	Checks low-resistance paths of electrical contacts, switches, etc.
15. Light meter.	Indicates light intensity.
16. Portable capacitance and resistance bridge.	Provides accurate readings of capacitance and resistance.
17. Safety equipment (rubber gloves, boots, mats; grounding sticks; tic tracer, etc.)	Provides for safe and efficient electrical maintenance.

the zero adjuster a sufficient amount to introduce mechanical-freedom or "play" but insufficient or disturb the position of the indicating pointer. This procedure will eliminate disturbances to the zero setting from subsequent changes in temperature, humidity, vibration and other environmental conditions. Once the VOM is zero adjusted, anyone ofa dozen measurements canbe made. The two more common tests are for AC voltage and resistance.

(l) AC voltage measurement. Outlined below is the procedure for measuring voltage in a circuit. Be careful when measuring line voltage, be sure that the range switch is set to the proper voltage position.

(a) Set the function switch at AC (fig 13-1).

(b) Set the range switch at the desired voltage range position. When in doubt as to the actual voltage present, always use the highes tvoltage range as a protection to the instrument. If the voltage is within a lower range, the switch maybe set for the lower range to obtain a more accurate reading.

(c) Plug a test lead in the– COMMON jack and another test lead in the + jack.

(d) Connect the test leads across the voltage source.

(e) Turn on power in the circuit being measured.

(f) Read the value on the scale.

(2) Resistance measurement. The procedure for measuring resistance is outlined below.

(a) Prior to measuring a resistance, the VOM must be adjusted to zero. Turn range switch to desire ohms range (fig 13-2). Plug a test lead in the – COMMON jack and another test lead in the + jack. Connect ends of test leads to short the VOM resistance circuit. Rotate the ZERO OHMS control until pointer indicates zero ohms. If pointer cannot be adjusted to zero, one or both the VOM internal batteries must be replaced. Before measuring resistance be sure power is off to the circuit being tested. Disconnect the component from the circuit before measuring its resistance.

(b) Set the range switch to one of the resistance range Positions.

(c) Set the function switch at either – DC or + DC. Operation is the same in either position. Adjust ZERO OHMS control for each resistance range as described in (a).

(d) Observe the reading on the OHMS scale at the top of the dial. Note that the OHMS scale reads from right to left for increasing values of resistance.

(e) To determine the actual resistance value, multiply the reading by the factor at the switch position.

(f) If there is a "forward" and "backward" resistance such as in diodes, the resistance should be relatively low in one direction (for forward polarity) and higher in the opposite direction. Rotate the function switch between the two DC positions to reverse polarity. This will determine if there is a difference between the resistance in the two directions.

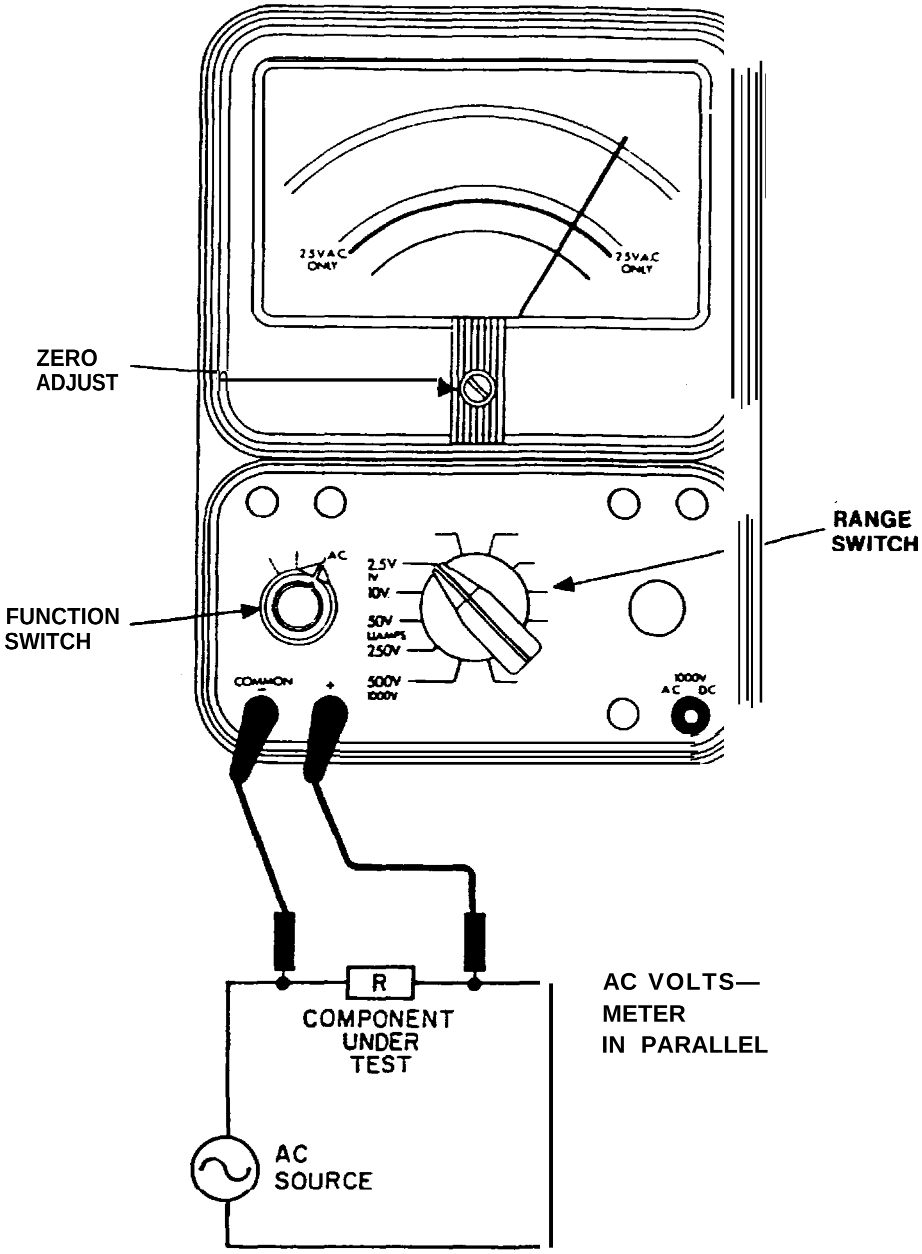

Figure 13-1. Set-up for measuring AC voltage.

13-3. Clamp-on volt-ammeter.

Most clamp-on volt-ammeters are designed to read alternating current only, although some types are available which will read direct current as well. Most are provided with plug-in leads so that the instruments can be used as voltmeters. Some models can also be used as ohmmeters. Refer to the manufacturer's instructions for operational procedures.

a. Application. Where a conductor is accessible at 600 volts or below, clamp-on volt-ammeters are used simply by clamping the instrument around insulated or noninsulated conductors. Thus with no interruption of service, the user may check motor loads and starting current for fractional-horsepower motors. Other applications include balancing polyphase systems, locating overloaded feeders, checking line voltages, trouble shooting fuse boxes and control circuits, repairing electrical appliances, and diagnosing miscellaneous operating problems. Although the clamp-on volt-ammeter is easy to use, care must be taken to obtain accurate readings. For example, be sure that the frequency of the circuit under test is within the range of the instrument. Many of these instruments are calibrated at 60 Hertz. Also, take care that stray magnetic fields do

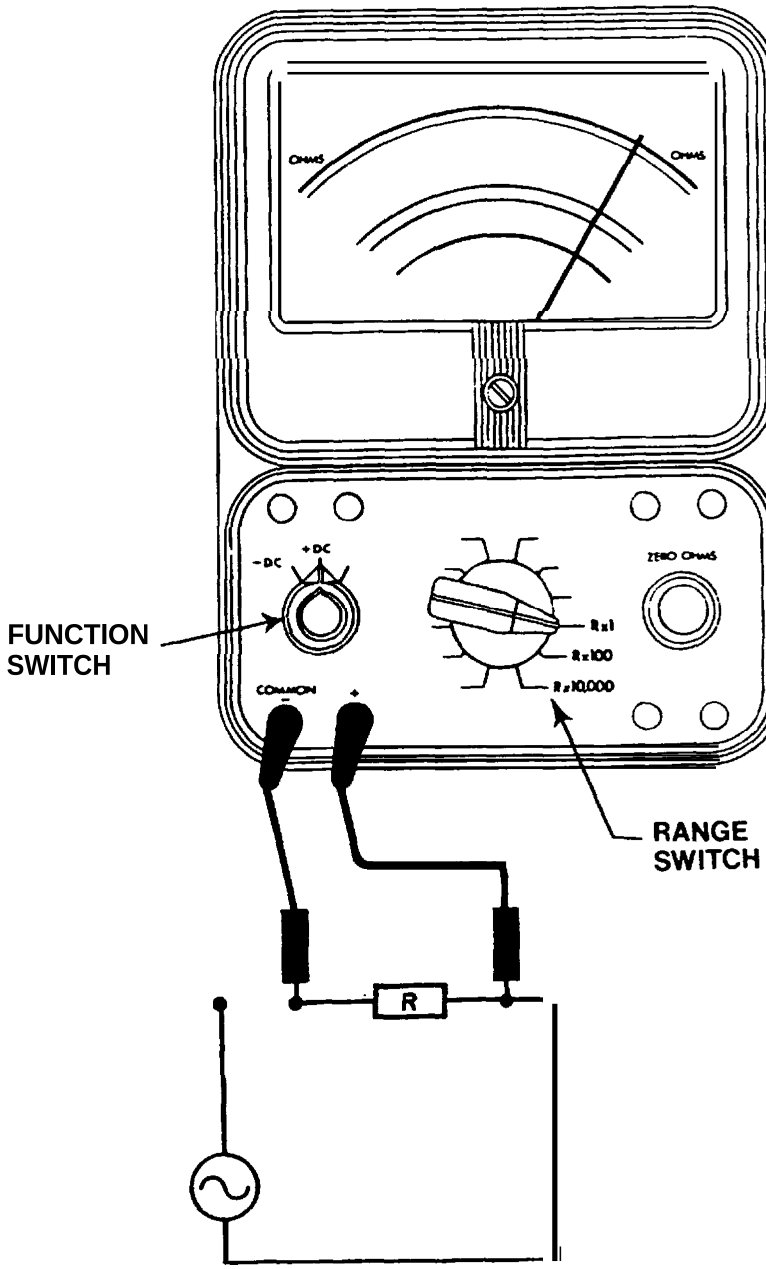

Figure 13-2. Set-up for measuring resistance.

not affect the current reading. When taking current readings, try to arrange conductors so that they are as far removed as possible from the conductor-under test. If testing is being done in a control panel, try to take the current readings at a location remote from relay magnet coils which could influence the accuracy of the reading. Also, avoid taking current readings on conductors at a point close to a transformer. Where a conductor is inaccessible at 600 volts or below, for instance in conduit or cable troughs, current can still be measured by using a current adapter in the fused disconnect switch. The cartridge-fuse type has three sets of adapters for various fuse sizes. The blade-fuse type is screwed onto the fuse holder in the switch box. The clamp-on ammeter function should not be used on pulsating dc because it will give erroneous readings.

b. Accessories. A clamp-on range extender permits the measurement of high currents beyond the range of the clamp-on volt-ammeter. The unit extends the current range ten times and allows an actual current reading of 1000 amps AC on the 0-100A meter scale. A current multiplier permits current measurement on low-current equipment. The device multiplies the load current by lx, 5x or 10x. A phase sequence indicating attachment is used in conjunction with the voltmeter circuit of the clamp-on volt-ammeter. To determine phase sequence, the circuit voltage is first measured. Then connections are made as shown in figure 13-3. If the meter reading is higher than the original circuit voltage, the phase sequence is black-yellow-red. If the meter reading is below original circuit voltage the phase sequence is red-yellow-black.

13-4. Megohmmeter.

The megohmmeter is an instrument used to measure very high resistances (fig 13-4). The megger consists of a hand-driven direct-current generator and a meter to indicate resistance in ohms. The meter used is an opposed coil type, having two coils, A and B, mounted over a gapped core (fig 13-5). The coils are wound on a light frame, and rotate around the core which remains stationary. The current for the coils is supplied by the hand-driven generator. To explain the operation of the unit, it is necessary to examine the action of the coils with the earth and lien terminals open; with these terminals shorted; and with a resistance (Rx) across these terminals. When these terminals are open, current flow is from the generator, through B and R which are in series with the generator. Since the terminals are open, no current flows through coil A to oppose movement and coil B will swing counterclockwise to a position over the gap in the core. In this position the pointer indicates infinity. With the terminals shorted together, a larger current flows through coil A than through coil B and the greater force in coil A moves the pointer clockwise to the zero position on the scale. Resistor R' is a current limiting resistor which prevents damage to the meter in this situation. If a resistance is connected across the terminals, current flows through coil A, R' and the unknown resistance Rx. This current attempts to move coil A clockwise, but the opposing force created by current through coil B tries to move it counterclockwise. The final position of the coils is determined by the magnitude of the current through Rx' and the coils will stop at a point where the forces tending to move them are at a balance. The pointer then indicates the value of the unknown resistance on the scale. No springs are used in the movement since the opposing forces in coils A and B balance the pointer when a reading is being taken. Having no springs to hinder its movement, the pointer floats freely back and forth across the scale when the meter is not in operation. Megohmmeters may be obtained with different voltage ranges; the more common being 500 and 1000 volts. The higher the resistance range to be measured, the higher the voltage required to actuate the movement for reading. Friction clutches are used to hold the generator to its rated voltage output. In operation, these clutches are designed to slip if cranked over a certain rate of speed, thus dropping the output to a safe value.

a. Safety precautions. When operating a megohmmeter, a very high voltage is generated at the output terminals which could prove fatal. The following safety precautions should be adhered to when operating a megohmmeter.

(1) Take the equipment to be tested out of service. This involves de-energizing the equipment and disconnecting it from other equipment and circuits.

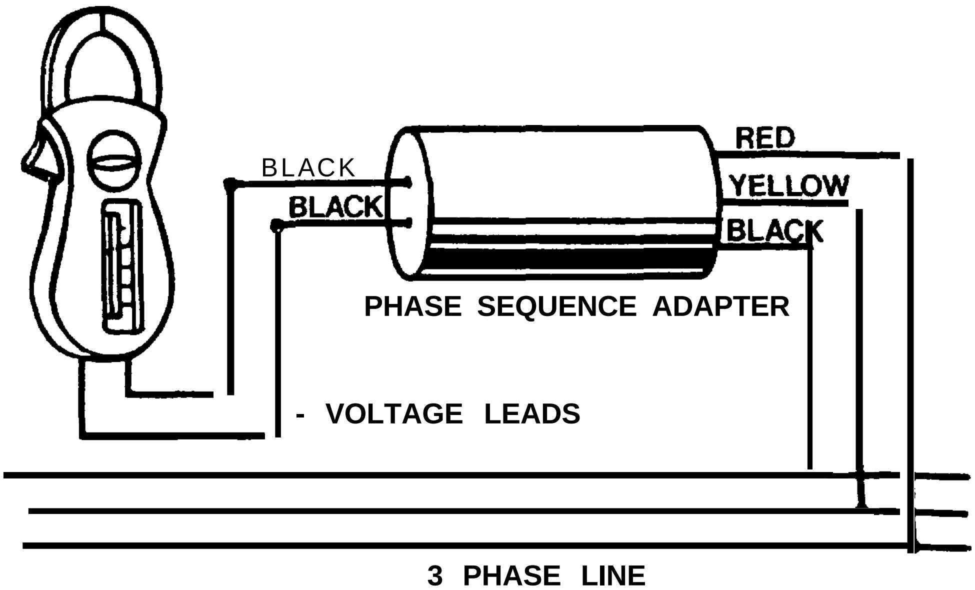

Figure 13-3. Setup for testing phase sequence.

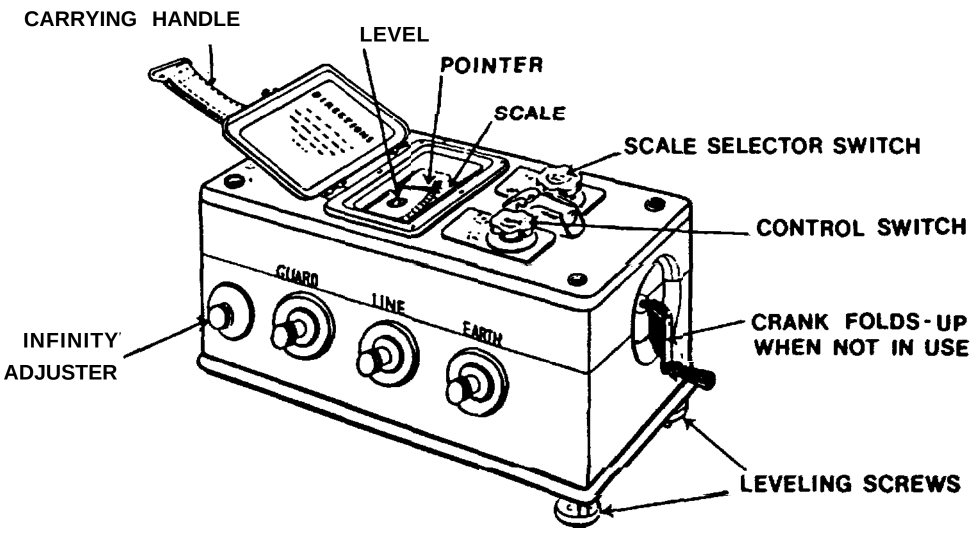

Figure 13-4. Megohmmeter.

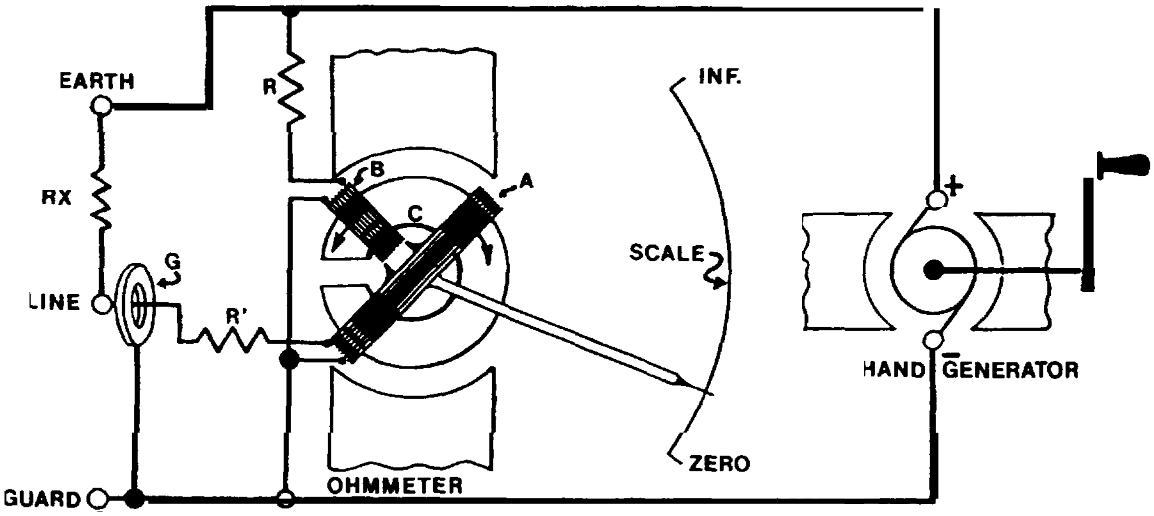

Figure 13-5. Diagram of megohmmeter connections.

(2) If disconnecting the equipment from the circuit cannot be accomplished, then inspect the installation to determine what equipment is connected and will be included in the test. Pay particular attention to conductors that lead away from the installation. This is very important, because the more equipment that is included in a test, the lower the reading will be, and the true insulation resistance of the apparatus in question maybe masked by that of the associated equipment.

(3) Test for foreign or induced voltages with a VOM (para 13-2). Pay particular attention once again to conductors that lead away from the circuit being tested and make sure they have been properly disconnected from any source of voltage.

(4) Large electrical equipment and cables usually have sufficient capacitance to store up a dangerous amount of energy from the test current. Therefore discharge capacitance both before and after any testing by short circuiting or grounding the equipment under test.

(5) Apply safety grounds.

(6) Generally, there is no fire hazard in the normal use of a megohmmeter. There is, however, a hazard when testing equipment is located in inflammable or explosive atmospheres. Slight sparking may be encountered when attaching test leads to equipment in which the capacitance has not been completely discharged or when discharging capacitance following a test. It is therefore suggested that use of a megohmmeter in an explosive atmosphere be avoided if at all possible. If testing must be conducted in an explosive atmosphere, then it is suggested that test leads not be disconnected for at least 30 to 60 seconds following a test, so as to allow time for capacitance discharge.

(7) Do not use a megohmmeter whose terminal operating voltage exceeds that which is safe to apply to the equipment under test.

b. Operation. The following are general directions for operating a hand-driven megohmmeter. For specific instructions, refer to the megohmmeter manufacturer's instructions. For megohmmeter connections when testing low voltage cables or motors, refer to paragraphs 6-3 and 4-5, respectively.

(1) Place the megohmmeter on a firm and level base. Avoid large masses of iron and strong magnetic fields.

(2) If the megohmmeter has a selector switch, set it to MEGOHMS + 1.

(3) Check infinity by turning the hand crank in a clockwise direction. The pointer should move promptly to infinity. This check is made with no connections to the test terminals. If the reading is not infinity, then use the INFINITY ADJUSTER to set the pointer to infinity.

(4) Check zero by short-circuiting the testing terminals. Turn the crank slowly. The pointer should move promptly to zero or off the lower end of the scale.

(5) Use well-insulated testing leads connected to the megohmmeter terminals and with opposite ends separated, turn the crank. If the pointer indicates less than infinity, there is a leak between the leads which must be removed before proceeding with tests. Touch together the test ends of the leads while turning the crank to make certain, by a zero reading, that the leads are not open-circuited.

(6) Apparatus to be tested must not be live. It must be taken out of service and disconnected electrically from all other equipment (para 13-4.1).

(7) Connect leads to apparatus to be tested. For testing to ground, connect from the LINE terminal to a conductor of the apparatus, and from the EARTH terminal to the frame of a machine, the sheath of a cable or to a good ground. For testing between two conductors, connect test leads to the two conductors.

(8) Turn the crank in the clockwise direction and observe the position of the pointer over the scale. It shows the value of the insulation resistance under test. Take the reading while operating and at a fixed time, preferably 30 or 60 seconds.

13-5. Harmonic measurements.

The increasing use of solid-state switching devices contributes to current wave forms which are nonsinusoidal. This distorted current wave form results in a distorted voltage waveform. This distorted wave form can be viewed as a fundamental 60 Hz sine wave with odd multiples of 60 Hz harmonics wave forms. Even harmonics are usually not present in an AC system, except under special circumstances. The common frequency range of harmonics is O-5 kHz with O-3 Khz being most common. If the harmonic levels are high, they may cause: interference to control and communication lines; heating of ac motors, transformers and conductors; higher reactive power demand and hence poor power factor; misoperation of sensitive electronics; overloading of shunt capacitors and, higher power loss. These harmonic currents will accumulate in the neutral conductor. Therefore, it is recommended that a double ampacity neutral conductor be used.

a. The purpose of harmonic measurements is:

(1) Monitoring existing values of harmonics and checking against recommended or admissible levels.

(2) Testing equipment which generates harmonics.

(3) Diagnosis and trouble-shooting situations where the equipment performance is unacceptable to the utility or to the user.

(4) Observations of existing background levels and tracking the trends in time of voltage and current harmonics (daily, monthly, seasonal patterns).

b. Basic equipment used for the measurement of nonsinusoidal voltage and currents. The techniques used for harmonics measurements differ from ordinary power system measurement. The harmonic measurements require more specialized instruments. Brief descriptions for three generic types of instruments used for harmonic measurements are included in this section.

(1) *Oscilloscope.* The display of the voltage wave-form on the oscilloscope gives immediate qualitative information on the degree and type of distortion. Sometimes cases of resonances are readily identifiable through the multiple peaks present in the current wave.

(2) *Spectrum analyzers. These* instruments display the signal as a function of frequency. A certain range of frequencies is scanned and all the components, harmonics and interharmonics of the analyzed signal are displayed. The display format may be a CRT or a chart recorder. For harmonic measurements, the harmonic frequencies must be identified by reference to the fundamental frequency. A wide range of analog and digital types of Spectrum Analyzers are available in the market.

(3) *Wave analyzers.* Harmonic analyzers or wave analyzers measure the amplitude (and also phase angle in more complex units) of a periodic function. These instruments provide the line spectrum of an observed signal. The cutput can be recorded or can be monitored with analogue or digital meters. An example of these is the Dranetz 636 disturbance wave analyzer. Again instruments with

a wide range of capabilities are available starting from printing results on a paper tape to automatic storing on a personal computer. Also several different manufacturers have similar instruments.

c. The use of harmonic measurement instruments and analyses of harmonic measurement results require more sophistication. Hence, it is recommended that outside resource and manpower is brought in for this type of work. Also if use of in-house personnel is desired, special training of those personnel is recommended before they are assigned to make such measurements.

13-6. Maintenance equipment guide.

Table 13-1 recommends the tool or piece of test equipment that should be used for a particular application.